Technical Specification: Reference: MOZ-TS-BP

System: Boundary planting

Main tree species

Miombo spp. for fruit and timber		
Cordia africana	Mutondo	Wild mango
Afzelia quanzensis	Chamfuta	Pod mahogany
Sclerocarya birrea	Amarula	Marula
Tamarindus indica	Tamalinoninho	Tamarind
Zisiphus Mauritania	Massanica	Zisiphus
Pterocarpus angolensis	Mbila	Wild teak
Millettia stuhlmanii	Panga panga	Panga panga
Strychnos innocua	Mutemo	
Kigelia Africana	Muvunguti	Sausage tree
Spirostachys africana	Mecunite	Tamboti
Brachystegia boehmii	Mfuti	Mufuti
Brachystegia spiciformis	Msasa	Msasa
Julbernadia globiflora	Muhimbie	Muhimbe
Swartzia madagascariensis	Pau rosa	Rosewood
Pterocarpus angolensis	Umbila	Rhodesian teak
Fuelwood and poles spp. (nitrogen fixing)		
Albizia lebbeck	Albizia lebbeck	Albizzia lebbeck
Timber spp.		
Khaya nyasica	Umbaua	Red mahogany

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Summary

This system involves the planting of mainly native hard wood tree species (typical of miombo woodland) along the perimeters of mashambas for timber, fruit and shade. This system will also sometimes be used to divide mashambas by creating internal boundaries and for along roadsides and pathways. Some fuelwood, nitrogen fixing, fruit and timber trees can also be planted. In the first years after planting farmers will be able to continue cropping around the trees right up to the edge of the mashamba.

Ecology

Altitudinal range. These species will grow mostly at low to medium altitudes (up to 1,000 m above sea level). Most will grow up to 1,500 – 2,000 m. Amarula will only grow up to 800 m.
Climatic factors – Typically Miombo species are very drought tolerant and frost sensitive. Typically annual precipitation in the range 700 – 2000 mm is required. Amarula, tamarind, ziziphus and mutemo will tolerate drier conditions (as low as 200 mm per year).
Habitat requirements – Typically Miombo species prefer well drained soils. Most of these species are very drought tolerant but will thrive on moist sites.

Growth habit

Cordia africana	Fast growing in early years to 4 – 15 m.
Afzelia quanzensis	Fast growing in first seven years to 24 m.
Sclerocarya birrea	Medium growth rates to 18 m.
Tamarindus indica	Large evergreen tree up to 30 m. Slow growing.
Zisiphus Mauritania	A medium sized tree with fast growth rate is first years. Extremely tolerant of adverse conditions
Pterocarpus angolensis	Slow growing deciduous tree up to 30 m. Pterocarpus is relatively fire tolerant and nitrogen fixing.
Millettia stuhlmanii	Medium growth rates to 15 – 25 m.
Strychnos innocua	Small, straight stem to 14 m. Occurs naturally in open woodland and rocky hills.
Kigelia Africana	
Spirostachys africana	
Brachystegia boehmii	
Brachystegia spiciformis	Slow growing. Will grow up to 8 – 25 metres with a broad flat crown

Julbernardia globiflora	Slow growing up to 25 metres
Swartzia madagascariensis	
Pterocarpus angolensis	Will grow to 30 m. Growth rate of 500 – 700 mm/year under favourable conditions.
Albizia lebbeck	Fast growing
Khaya nyasica	A large tree which will achieve fast growth rates on moist, well drained alluvial soils (up to 60 m).

Main timber products.

Cordia Africana	Fruit, timber and a good tree for apiculture
Afzelia quanzensis	Hard timber, easy to work, durable and resistant to termites. Used for construction, boat building, furniture, flooring and turning
Sclerocarya birrea	Light, soft timber suitable for crafts and furniture
Tamarindus indica	Very hard durable timber. Will take a fine polish and can be used for general carpentry.
Zisiphus Mauritania	Medium weight hardwood which is durable but will split easily. Can be used for construction and furniture. Excellent fuelwood
Pterocarpus angolensis	High value, very durable timber. Also useful for medicine, apiculture, fodder and tannins.
Millettia stuhlmanii	Useful for bee hives and apiculture
Strychnos innocua	Use for fuel wood, fodder, food timber and medicine
Kigelia Africana	
Spirostachys africana	
Brachystegia boehmii	
Brachystegia spiciformis	The wood is reddish-brown, coarse, not durable, difficult to season, subject to termite attack, tends to twist, split and warp. Even when treated, it is a rather inferior general purpose timber. It can be used for furniture and railway sleepers.
Julbernardia globiflora	
Swartzia madagascariensis	
Pterocarpus angolensis	High value, durable timber suitable for all carpentry uses / easy to work.
Albizia lebbeck	Fuel wood and poles
Khaya nyasica	Furniture, timber frames, veneer and dugout canoes

Classification of climate/ site productivity

Climate is classed as optimal and sub-optimal based on available ecological information and experiences within the project. (The use of this system in areas classified as sub-optimal for climatic conditions is not recommended.)

Optimal	Description of climate Range - 0 – 1,000 masl Range - 700 – 1,500mm/yr
Sub-optimal	Description of climate Range - 1,000 – 2,000masl Range - 350 – 2,500 mm/yr

Site productivity is inferred from locally reported soil conditions for the site

	High	**Medium**	**Low**
Soil type	Deep (>30cm), well drained, brown-black, few stones	20-30cm depth, heavy clays or sandy	Thin (<20cm), stoney, compacted soils or oxidised clays

Management objectives

Planting around perimeter of the mashamba to provide timber, fuel wood and fruits. Boundary planting will also provide shade and contribute to soil conservation

Potential income
Any income generated using this land use system is likely to be small. Trees will be managed for fuelwood, poles and timber production. Timber prices may vary substantially.

Costs of implementation
Estimated costs per **100 m**:
Establishment (year 1):500 Meticais ($25)
Maintenance (year 2 – 5): 200 Meticais ($10)
Opportunity cost (lost production from land): N/A

N.B. The above costs include values for the purchase of seedlings and for time that the farmer would spend on establishment and maintenance of the trees. However, in the first years of the project (during the Pilot Phase) seedlings are supplied at no cost to the farmer and most farmers will plant and maintain their own trees so this is not actually a cost that will be incurred.

Management operations

Establishment
All competing vegetation should be removed and the foliage left on site to act as an organic fertilizer, and to conserve soil moisture. Trees should be planted in a single row **4** meters apart. Trees planted for fuel wood, poles and soil improvement (Albizia) should be planted between timber trees. These trees will be coppiced and thinned out over time.

Crops may be grown between the trees during the first years until canopy closure. In the first year these crops should be planted after the trees have been planted.

It is best to plant at the beginning of the wet season to minimize the requirement to water the seedlings. Mulch (in the form of organic green material from e.g. competing vegetation or interplanting) should be placed around the base of the seedlings to help retain soil moisture whilst also reducing the growth of competing vegetation and adding fertility to the soil.

When planting:
- Care should be taken handling plants not to cause damage to shoots, buds or bark
- Only remove plastic from around root-ball at the time of planting. Care should be taken to remove all the plastic
- Prune back roots (especially any circular roots) at the time of planting to stimulate new root growth once in the ground
- Plant to depth of root collar (i.e., for bagged plants, to level of existing soil). Never plant deeper than in nursery leaving no roots exposed.
- Ensure that soil is replaced firmly around trees (i.e., well heeled in). Put top soil back in planting hole first

NB. Where appropriate it is also possible to plant more than one row of boundary planting around the mashamba (up to a maximum of 3 rows). Where this occurs planting should be staggered. Rows should be planted 3 metres apart.

Maintenance
The removal of all competing vegetation will be required twice a year for the first three years after planting, or until the trees have reached a height of 1.5 - 2 m. Weeding intensity can be reduced to once per year after the third year until approximately the sixth year (or once the trees are no longer in competition with weeds).
Prune side branches of timber trees to create clear boles of high value and also to allow more side light to penetrate the mashamba. Offcuts can be used for fuel wood.
No burning is allowed at any time. Any foliage should be worked into the soil. Fire breaks should also be maintained between mashambas.

All seedlings will require protection from goats.

Thinning and harvest
Coppice albizia on 3 – 10 year cycle for fuel wood and poles to be used in construction.

Re-establishment
Fell and re-establish timber trees at year 60. (Tamarind and Umbila should be harvested on a 100 year rotation).

Carbon sequestration potential
Carbon sequestration potential over ***100*** years on an average quality site with optimal climatic conditions is ***3.23*** tC/100m (per row planted) above an initial vegetation carbon baseline which is assumed to be zero. The Nhambita carbon calculator (ECCM, 2005) should be used to calculate the number of saleable carbon credits based on the land use system and area planted.

Carbon sequestration potential is based on average net carbon storage in biomass and forest products. Carbon storage is calculated using the CO2FIX-V3 model (Mohren et al 2004). Details of the parameters used (basic wood carbon content; timber production; total tree increment relative to timber production; turnover rate; product allocation for thinnings and expected lifetime of products) are given below. The CO2FIX model calculates carbon storage per hectare. ECCM has assumed that 100 m planted is equivalent to 5% of one hectare.

The carbon sequestration potential of this system has been calculated using the species composition and assumed annual timber production shown in the table below:

Tree species	**Proportion of planting (%)**	**Mean Annual Increment (m^3/ha)**
Albizia	36[1]	12.0
Mbila	20	5.9
Red mahogany	25	11.2
Amarula	10	5.8
Panga panga	10	4.6
Tamarind	20	3.5
Zisiphus	15	5.4

This species composition is likely to be representative of actual planting and growth data (CAI) has been obtained for these species which can be used to model carbon sequestration.

N.B. Stem increment (CAI and MAI) was calculated on the basis of trees measured within the project area. The number of trees measured so far is relatively small. As the project expands and more data becomes available these calculations might be revised and updated.

N.B.B **3.23 tonnes of carbon** is equivalent to **11.8 tonnes of carbon dioxide**.

Monitoring
Monitoring targets for the first 4 years are based on establishment; the whole plot must be established by the third year with at least 85% survival of seedlings. Thereafter monitoring targets are based on DBH, the expected DBH at the time of monitoring is based on a predicted mean annual diameter increment on which carbon sequestration estimates are based.

Year	**Indicator**
1	At least 35% plot established
2	At least 70% plot established
3	Whole plot established, 85% survival At least ***21***. stems / 100 m planted
4	Whole plot established
5	Average DBH not less than 6cm
6	Average DBH not less than 7cm
7	Average DBH not less than 9cm
10	Average DBH not less than 13cm

Additional information
Cashew
Important pests to cashew trees include sucking bugs (*Helopeltis schoutedeni* and *H. anacardii*), the theraptus bug (*Pseudotheraptus wayi*), thripts (*Selenothrips rubrocinctus*), bark borers (*Mecocorynus loripes*) and the defoliating caterpillar (*Nudaurelia bellina*) (World Agroforestry Centre, 2004).

[1] An additional 36% has been assumed to model carbon sequestration using the boundary planting system which is made up of Albizzia. Most of this is likely to be thinned out by year 25. This compensates for the closer spacing of the boundary planting using this system (4m x 4m) as compared with other systems (e.g. woodlot) where trees are planted at 5m x 5m.

Common diseases include die-back or pink disease (*Corticium salminicola*), damping-off of seedlings (*Phytophthora palmivora*); anthracnose disease (*Collectotrichum gleosporioides*), leaf spots, shoot-rot and leaf fall. A combination spray of BHC and a copper fungicide like Blitox at the time of emergence of new flush has been found an effective prophylactic measure (World Agroforestry Centre, 2004).

<u>Amarula</u>
Psyllid mites, aphids and wood susceptible to termite and wood borer attack.

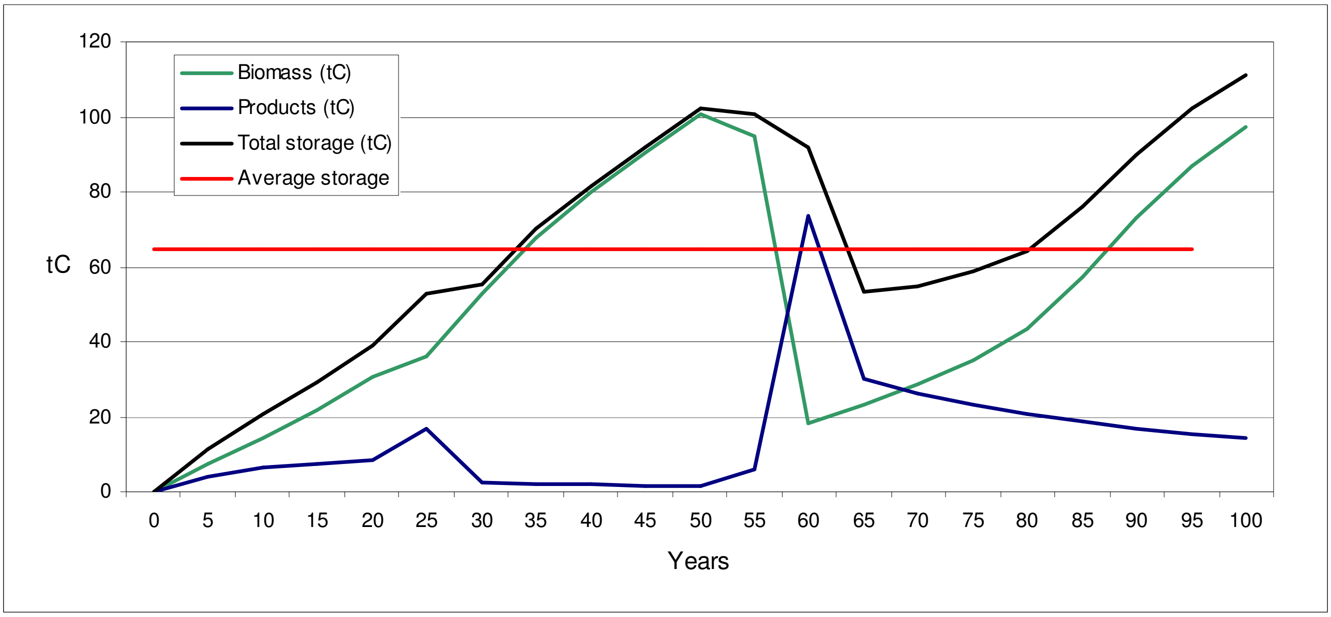
<u>Tamarind</u>
Scale insects, mealy bugs and borers

<u>Ziziphus</u>
Fruit flies can be a major cause of crop loss

<u>Red mahogany</u>
Shoot borer (will damage leading stem and reduce timber quality)

Appendix 1 Carbon storage figures

Year	Biomass (tC)	Products (tC)	Total storage (tC)	Accumulated tCyr
0	0	0	0	
5	7.4658	4.086	11.6	36.0
10	14.5343	6.2712	20.8	116.2
15	21.7169	7.5888	29.3	237.6
20	30.417	8.4456	38.9	402.5
25	36.0465	16.56	52.6	627.0
30	52.739	2.4876	55.2	871.3
35	67.884	2.0556	69.9	1192.4
40	79.7975	1.746	81.5	1578.4
45	90.322	1.5228	91.8	2016.9
50	100.7955	1.3572	102.2	2507.1
55	94.604	6.1719	100.8	3005.0
60	18.382	73.3933	91.8	3519.1
65	23.096	30.1493	53.2	3801.8
70	28.696	26.3378	55.0	4072.4
75	35.176	23.3795	58.6	4357.6
80	43.4785	20.8889	64.4	4666.7
85	57.0475	18.782	75.8	5020.0
90	72.897	16.9877	89.9	5441.5
95	86.877	15.457	102.3	5929.2
100	97.184	14.1403	111.3	6469.4



Appendix 2 - CO2Fix Inputs

Stand parameters		
Rotation length (yr)		**Tree species** / **Rotation length**: Albizia 25; Red mahogany 60; Amarula 60; Panga panga 60; Tamarind 100; Zisiphus 60; Mbila 60
Number of rotations		2 (only 1 rotation for albizia)
Adjustment of assimilate to account for non-optimal site conditions	Foliage	1
	Branches	1
	roots	1
Initial biomass (Mg/ha)*	Foliage	0
	Roots	0
	Litter	0
	Branches	0
	Stems	0
	Deadwood	0

Tree species	**Rotation length**
Albizia	25
Red mahogany	60
Amarula	60
Panga panga	60
Tamarind	100
Zisiphus	60
Mbila	60

*The initial biomass (baseline) will be subtracted by the project staff on a case by case basis.

Stem increment **CAI** (m3/ha/yr)								Dry weight increment relative to stem		
								foliage	branches	roots
Year	Albizia	Red mahogany	Amarula	Panga panga	Tamarind	Ziziphus	Mbila	0.35	0.2	0.25
5	12.0	2.3	0.5	1.7	0.3	3.9	0.6			
10		2.3	0.5	3.5	0.3	6.4				
15		4.6	1.0	6.9	0.7		1.3			
20		9.1	1.9	6.2	1.4		2.6			
25		23.0	4.9	5.4	2.7		3.8			
30		24.0	5.5	4.6	2.6		5.1			
35		20.8	6.1	3.9	4.5		6.3			
40		13.2	6.8	3.1	5.8		7.6			
45			7.4	2.3	6.4		8.9			
50				1.6	6.5		10.1			
55					5.9		11.4			
60					4.7		12.6			

Tree species Parameters		
Basic density of stemwood (kg/m^3)		(see table below)
Carbon content of dry matter (proportion of dry weight)		0.5
Turnover of various biomass components (1/yr)	Foliage	1
	Branches	0.05
	Roots	0.07
Mortality as a fraction of trees per year (1/yr)		0.0
Average residence time of carbon in wood products (1/yr)	Dead wood	10
	Energy	1
	Packing	5

Tree species	**Kg/m^3**
Albizia	600
Red mahogany	590
Amarula	590
Panga panga	720
Tamarind	750
Zisiphus	760
Umbila	640

	Construction	25

Thinning and harvest table						
Thinning age (Yr)	Species	Fraction stem removed	Dead wood	Energy	Packing	Construction
5	Albizia	50	0.0	0.8	0	0.2
10	Albizia	50	0.0	0.8	0	0.2
15	Albizia	50	0.0	0.8	0	0.2
20	Albizia	50	0.0	0.8	0	0.2
25	Albizia	100	0.0	0.8	0	0.2
60	Miombo & timber spp.	100	0.0	0.3	0	0.7
100	Tamarind	100	0.0	0.3	0	0.7

References

ECCM (2005). Nhambita carbon calculator

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